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Press Bul. 20, Issued July 25, 1907.

Hawaii Agricultural Experiment Station,

HONOLULU

J. G. SMITH, Special Agent in Charge.

PRESS BULLETIN NO. 20.

THE INTRODUCTION OF TOP-MINNOWS

(Natural Enemies of Mosquitoes)

INTO THE HAWAIIAN ISLANDS.

In Coöperation with the Board of Health, Territory of Hawaii and Leland Stanford Junior University.

By D. L. Van Dine,

Entomologist, Hawaii Agricultural Experiment Station, United States Department of Agriculture.

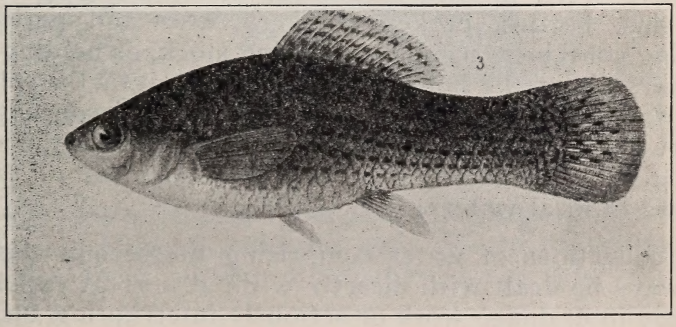

Fig. 1.—Top-Minnow, *Mollienesia latipinna.* (U. S. Fish Commission.)

In December, 1902, a survey of Honolulu and vicinity was begun to determine the character and location of the bodies of water responsible for the great numbers of mosquitoes that

were common at nearly all seasons of the year. The places in which mosquitoes were found to breed can be classed under two general heads: (1) Such collections as in containers for storing water (tubs, barrels, troughs, water-tanks, etc.); cesspools; surface sewers and the catch-basins; discarded tins, bottles, and cans in vacant lots and on rubbish heaps; neglected gutters and defective plumbing; and vessels holding water in and about dwellings and out-houses (flower vases, drinking cans in chicken yards, containers under table legs and flower pots, etc.); and (2) the collections of water as taro-patches; rice fields; reservoirs; irrigation ditches; swamps; closed pools; ponds; temporary pools formed by storm water on the lower levels; and pools in the beds of streams during the dry seasons.

The breeding places included in the first class are responsible for the larger part of the number of mosquitoes in any locality. They are entirely responsible for the mosquitoes in the business section of the city and in those residential portions that are at any distance removed from the collections of water enumerated in the second class of breeding places. To obtain relief from the mosquitoes that breed in the collections of water of the first class it is demanded that systematic inspection work be carried on continuously throughout the infested district. This inspection must be followed by active measures of prevention, that is, preventing the development of the mosquito larvae or wrigglers in any body of water discovered that is capable of acting as a breeding place. The preventive work implies screening, draining, oiling, hauling away tins, bottles, broken crockery, etc., and periodically emptying containers used for watering stock, or holding plants or flowers about the house. Emphasis is given this phase of mosquito control at this time to prevent a misconception on the part of the people of this Territory in regard to the amount of relief to be expected from the establishment of the top-minnows in local waters.

The collections of water comprising the second class cannot always be dealt with directly without a great expenditure of money in drainage work or seriously interrupting such agricultural operations as rice and taro culture. It is obvious, then, that while any natural check or enemy of mosquitoes is desirable, it is particularly to be desired in the case of mosquitoes developing in these bodies of water. Previous to the

successful introduction and establishment of the top-minnows in Hawaii no effective enemies of mosquitoes occurred.[1] The dragon-flies or mosquito-hawks and the gold-fish were their only important enemies but neither are special mosquito feeders, although the winged dragon-fly devours many adult mosquitoes in the air and the gold-fish feeds on the larvae to a certain extent in the water, especially when confined in a fountain, lily-pond, or aquarium.

The question of introducing the top-minnows into Hawaii was first considered in the early part of 1903, these fish having been reported as effective enemies of mosquito wrigglers elsewhere.[2] Dr. David Starr Jordan, to whom the problem was referred, replied that these fish had never been transported such a distance but, while the whole undertaking would be an experiment, the fish were extremely hardy and the greatest consideration would be the cost of the work. Because of the cost this phase of mosquito control did not receive further notice at that time.

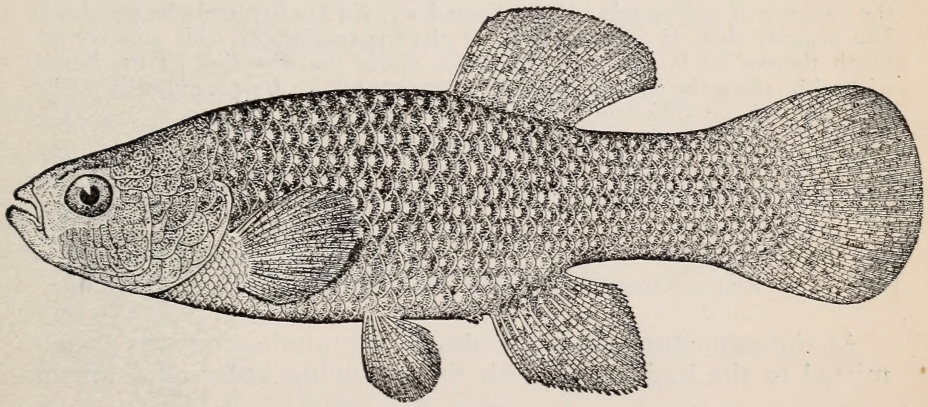

Fig. 2.—Top-Minnow, *Fundulus grandis*. Enlarged. (U. S. Fish Commission.)

During 1904 a Citizens' Mosquito Campaign Committee was organized in Honolulu and this body was instrumental in providing the means for the introduction of the fish. The writer

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[1] The species introduced were *Mollienesia latipinna Fundulus grandis*, and *Gambusia affinis* of the family *Poeciliidae* collected and transported to the Islands from Seabrook near Galveston, Texas, by Mr. Alvin Seale. See figures number 1, 2, and 3.

[2] L. O. Howard. Mosquitoes, New York, 1901.

had an opportunity to discuss the subject personally with Dr. Jordan and in the interview Dr. Jordan offered to send an expert from Stanford University to collect the fish and bring them to Hawaii on condition that the Territory pay simply the expenses of the undertaking. This offer was fully appreciated by the Territory. On a recommendation from the Citizens' Mosquito Committee, the Governor presented an item of $1500 to the Legislature of 1905 to cover the expenses of the experiment. The communications on the subject were as follows:

(Letter from the Citizens' Mosquito Committee to the Governor.)

Honolulu, Hawaii, March 12, 1905.

Hon. George R. Carter,
Governor of the Territory of Hawaii, Honolulu.

Sir: Dr. David Starr Jordan, of Stanford University, having offered to send an expert of that institution to collect for these islands certain fish of the Southern States and Mexico, at present entirely unrepresented here, that feed upon the larvæ of mosquitoes, providing the Territory pay the expenses of such trip, the undersigned, at your request, beg to say that for the expense of such a trip a sum of not less than $1,500 should be provided. We suggest that, if appropriated for the above purpose, this sum, or as much thereof as is necessary, be spent under the direction of the board of health, since the president of that department of the government is the chairman of the Citizens' Mosquito Committee.

Very respectfully yours,

CHAS. B. COOPER, M. D.,
Chairman Legislative Committee.

D. L. VAN DINE,
Chairman Advisory Committee.

Representing the Citizens' Mosquito Committee of Honolulu.

At the opportune time the above communication was transmitted to the legislature with the following indorsement:

(Letter of May 10, 1905, from Governor Carter to the legislature.)

To the Legislature of the Territory of Hawaii:

Herewith, I transmit for your consideration copy of a letter of March 12, containing a proposal made by Dr. David Starr Jordan, of Stanford University, to provide an expert, with the necessary apparatus, to undertake the importation into these islands of a certain small and vigorous fish found in Mexico that feeds on the larvæ of the mosquito, provided the Territory simply pays the expense of such an undertaking.

You are aware that the only fish we have at present exclusively occupying our fresh waters is a species of mud fish, commonly known as the oopu, and the gold fish. You are also aware that there is known to exist here the species of mosquito which carries the germs of yellow fever, which, fortunately for us, has not as yet been inoculated, but with the completion of the Panama Canal it will only be a question of time before cases of

this or some other disease will reach this port. Every interest in the Territory would be advanced if this mosquito could in some way be entirely eradicated, or at least reduced to the smallest possible number.

G. R. CARTER,
Governor.

The subject was referred to the health committee of the House. The committee reported favorably and the item ($1500.) was included in the general expense bill of the Territorial Board of Health for disbursement. This money was not available until July 1st, but as soon as possible thereafter an advance was sent to Mr. Alvin Seale at Stanford University, the man selected by Dr. Jordan to carry on the experiment.

The following report by Mr. Seale covers the work of collecting the fish and their transportation to Hawaii:

REPORT OF MR. SEALE.

Honolulu, Hawaii, September 23, 1905.

Mr. D. L. Van Dine,
Entomologist, U. S. Experiment Station,
Honolulu, H. T.

Dear Sir:—In accordance with the following letter to yourself from Dr. David Starr Jordan, I was chosen to attempt the introduction of "top-minnows" or "killifish" into the Hawaiian Islands for the purpose of destroying the larvae of mosquitoes:

LELAND STANFORD JUNIOR UNIVERSITY.

Office of the President.

Stanford University, Cal., April 18, 1905.

Mr. D. L. Van Dine,
United States Experiment Station,
Honolulu, Hawaii.

Dear Sir:—The best place to collect the fishes which you want would doubtless be in Louisiana. It would probably take no longer time to bring them from there than from any other places nearer. Perhaps an equally good place would be Tampico, on the edge of Mexico. You understand that this would necessarily be an experiment. These little fishes feed freely on mosquitoes. Some live in brackish water, some in fresh water, and all of them are very hardy. But no one has ever tried to transplant any of them, and the whole thing might turn out, for some reason or other, to be a failure. Especially one would need to experiment on feeding the little fishes during their transportation. The genera which I would recommend are Mollienesia, Adinia, Gambusia, and Fundulus. Some of these are viviparous, others lay eggs. Whoever undertakes this should give a good deal of attention to the question of feeding the little fishes,

and for this purpose perhaps a tank breeding mosquitoes would be as good as anything. The best time to undertake it would be about the 1st of June. I will select some one as soon as I hear from you.

Very truly yours,

DAVID S. JORDAN.

On receipt of yours of July 11, 1905, with the advance of $500 of the Territorial appropriation covering the expenses of this undertaking, I started from Stanford University to the Southern United States. It was my intention to secure the top-minnows at or near New Orleans, but the rigid quarantine in operation in Louisiana prevented my carrying out this plan. Seabrook, near Galveston, Texas, was then selected as the next place most available. At Seabrook I found the family of top-minnows, *Poeciliidae*, in large numbers. They were swarming in all the stagnant waters at sea-level as well as in various ditches, ponds, and standing pools. Mosquitoes are very plentiful in and about Seabrook, but after a study of the situation I am convinced that their source is not the bodies of water containing these fish but rather temporary and artificial breeding places, such as closed pools, tubs, tin cans, and other refuse which are not accessible to these fish.

As per his letter to you, Dr. Jordan recommended the following genera: *Mollienesia, Adinia, Gambusia* and *Fundulus*. These are all members of the single family Pœciliidae or top-minnows. I first made a careful examination of a number of the stomachs freshly taken from members of the above genera. The stomach-contents was found to consist largely of larvae of various insects, including those of mosquitoes; egg-masses of mosquitoes; minute crustaceæ and some vegetation. The results showed that Gambusia were the best insect feeders. Of 100 stomachs of this genus examined all contained many insect larvae and eggs among which I noticed especially numerous egg-masses of the mosquito. However, Mollienesia, Fundulus and Gambusia differed slightly in regard to their capacity for the various insect larvae and the difference was probably due to the different food localities. The temperature of the water in and about Seabrook in which these fish were found ranged from 74° to 87°.

It now remained to determine under what conditions the fishes could be most successfully transported to Hawaii. Six ordinary ten-gallon milk cans were prepared by puncturing the covers with numerous holes and placing the cans in bran sacks, the intervening space being tightly packed with Spanish moss. This served to keep the water at an even tempera-

ture. Two hundred fish were placed in each can. The following morning so many were dead that it was evident the cans were overcrowded and I reduced the numbers to one hundred.

Experiments were conducted as follows:

Can No. 1. Allowed to stand undisturbed. Water unchanged and unaerated. Temperature normal. The first morning six fish were dead. The second day, two died. The third day the fish were perfectly lively and were taking food freely. The fifth day five died and by the eighth twenty had died. The experiment was not carried further.

Can No. 2. Water changed once each day. Temperature normal (ranged from 74° to 78°). During the first three days there were four deaths. The eighth day two died. After this time there were no more deaths. Fish fed freely on mosquito larvae, and prepared fish food.

Can No. 3. Water changed twice each day. Temperature normal. Three deaths the first night. After this time there were no more deaths. Fish fed freely on mosquito larvae and prepared fish food.

Can No. 4. Water changed every two days. Temperature normal. Five deaths the first three days, after which no fish died. Fish fed freely, keeping constantly at top of the water.

Can No. 5. Water slowly and very gradually reduced in temperature to 40°. Fish would not feed at the end of six days. During this time eighteen had died. Experiment discontinued.

Can No. 6. Water reduced slowly to freezing point, then can packed in ice. At the end of six days all but three of the fish were dead. Experiment discontinued.

The above experiments demonstrated that the fish should be transported in water at the normal temperature and gave the necessary information in regard to the frequency of changing the water.

The three most abundant species, *Gambusia affinis, Fundulus grandis* and *Mollienesia latipinna*, were collected and approximately seventy-five placed in each can. On Sept. 4, 1905, I left Seabrook, Texas, on the long journey to Honolulu. A 20-gallon tin tank was taken along as a supply reservoir.

The following routine work was observed during the entire trip: At 8 a. m. the fishes were fed sparingly on prepared fish food, finely ground liver or hard boiled eggs; at 9:30 half the water in each can was siphoned off from the bottom, thus cleaning out the cans and removing all uneaten food and

excrement, and an equal amount of fresh water added; at noon the cans were all aerated by means of a large bicycle-pump, a sponge being tied over the end of the hose to separate the air into fine particles; at 4 p. m. two gallons of water were siphoned off from the bottom and two gallons of fresh water were put in; just before retiring the cans were again aerated by means of the air-pump.

At each place en route where the water was changed it was first tested by placing two fish in a bucket containing the new water at the proper temperature. At El Paso, Texas, only, did the water kill the fish thus treated. After ten minutes the two fish were dead, probably due to the alkali it contained. The water at Los Angeles was good as also the San Francisco water, which was used from the latter place to Honolulu, an abundant supply being carried on the steamer. The water used from El Paso to Los Angeles was taken from the supply tank, filled at San Antonio, Texas.

Twelve fish died between Galveston and San Francisco and only fifteen between San Francisco and Honolulu. The fish were landed in Honolulu from the S. S. "Alameda" on September 15, 1905, the trip from Texas occupying 12 days and 27 of the approximate 450 fish were lost.

The fish were in fine condition on arrival and as prearranged by yourself were placed in the breeding ponds prepared for them. The temperature of the water about Honolulu is almost identical with that where the fish were collected, and the appearance of the fish at this writing indicates that they should thrive on the Islands. The fish should be confined in the present breeding ponds, where they can be prevented from going out to sea or falling prey to other fish until their increased numbers permit general distribution to other localities in the group.

Very truly yours,

ALVIN SEALE,

Assistant, U. S. Fish Commission.

Upon the arrival of the steamer the fish were taken at once to Moanalua near Honolulu where, through the courtesy of Hon. S. M. Damon, a series of four ponds had been prepared for their reception and breeding. An irrigation ditch led clear water to the ponds through a gate-way guarded by wire cloth of a fine mesh. The outlet was guarded in a similar manner. The water was allowed to circulate through three of the ponds but no outlet was provided for the fourth in order that the water might remain standing. Two of the ponds were about

two feet in depth with one free from vegetation and two were from two to six inches in depth, with one also free from vegetation. These varying conditions represented somewhat the shallow waters of the Islands as regards depth, temperature, presence or absence of vegetation and standing or running water. About equal numbers of the fish were placed in each of the four ponds.

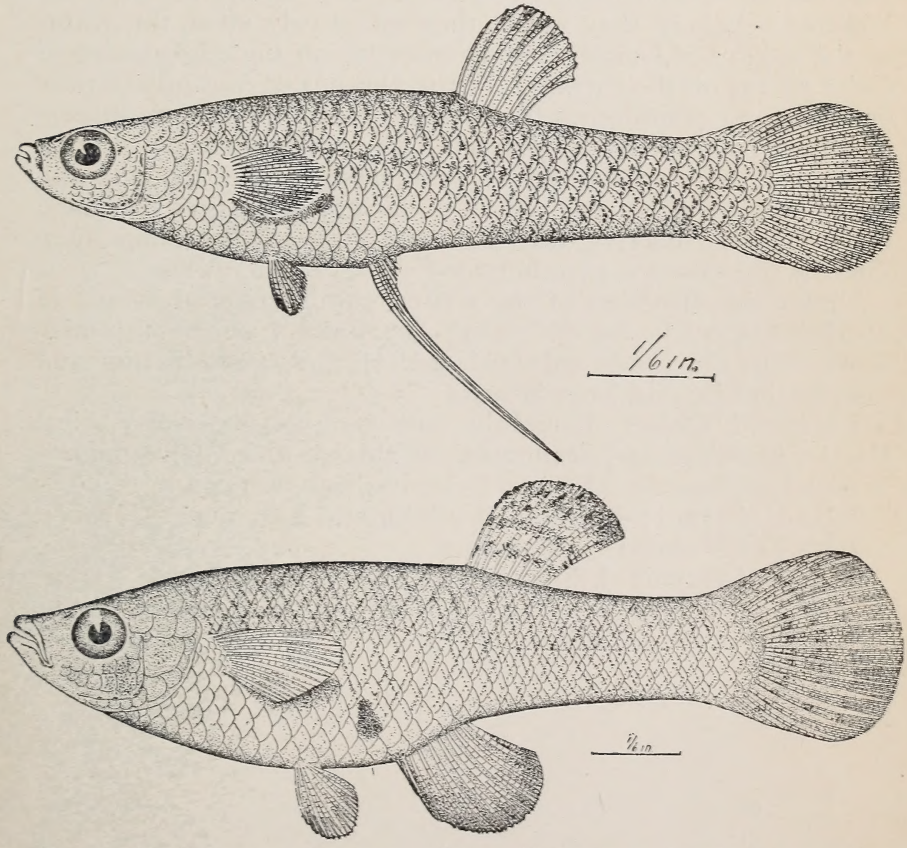

Fig. 3.—Top-Minnow, *Gambusia affinis*. Male above, female below. Enlarged. (U. S. Fish Commission.)

The fish thrived in all of the ponds almost equally well, the main advantages of their confinement being the prevention of their being carried out to sea by a freshet and the protection from other predaceous fish.[3] It was determined, however, by

[3] Dr. Jordan informed the writer that the Hawaiian fish likely to prey upon the top-minnows were *Sphyraena snodgrassi* (Kaku) in the mullet ponds, Elops (Awa-Aua), and Kuhlia (Aholehole).

observation at the ponds and in other locations where the top-minnows were liberated later that they thrived best in shallow, standing water at a temperature ranging from 76° to 82° F. The fish show no inclination to go out to sea and avoid the deep water, lessening the probability of their being eaten by the larger predaceous fish.

They have multiplied rapidly and from the few hundred introduced, several hundred thousand have been bred and distributed. Where they occur they effectively clear the water of the mosquito larvae, feeding likewise on the egg-masses of *Culex pipiens* on the surface. In the absence of mosquito larvae or eggs the top-minnows feed upon the smaller aquatic insects of other species, as the nymphs of the water boatman, *Corixa blackburni*, eating also various small insects that fall into the water and are drowned. In an aquarium the larger fish have been observed making way with the very small of their own kind in the absence of other food.

Under the direction of the writer, the Territorial Board of Health has made the following distribution of the top-minnows from the funds appropriated for their introduction and distribution by the Legislature:

Island of Oahu: Honolulu and vicinity generally, Aiea, Pearl City, Waialua, Maunawai, Wahiawa and Waimanalo.

Island of Hawaii: Hilo and vicinity, and Paauhau.

Island of Maui: Kahului, Wailuku and Lahaina.

Island of Molokai: Kalaupapa.

Island of Kauai: Lihue, Eleele, and Waimea.